# A METHODOLOGY FOR DETERMINING COMMAND, CONTROL, AND COMMUNICATIONS (C3) REQUIREMENTS FOR REMOTELY PILOTED VEHICLES (RPVs) AND UNMANNED DRONE AIRCRAFT

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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

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by

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March 1980

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T197428

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>A Methodology For Determining Command, Control, and Communications (C3) Requirements For Remotely Piloted Vehicles (RPVs) and Unmanned Drone Aircraft | | 5. TYPE OF REPORT & PERIOD COVERED<br>Master's Thesis;(MAP 80)<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>John Harvey Newton | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Naval Postgraduate School<br>Monterey, California 93940 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Naval Postgraduate School<br>Monterey, California 93940 | | 12. REPORT DATE<br>March 1980<br>13. NUMBER OF PAGES<br>68 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)<br>Naval Postgraduate School<br>Monterey, California 93940 | | 15. SECURITY CLASS. (of this report)<br>Unclassified<br>15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Command, Control, Communications (C3), Command-Control (C2), RPV, Remotely Piloted Vehicle, Unmanned Aircraft, Remotely Piloted Aircraft, RPA, Drone, Unmanned Drone Aircraft, C3 Requirements, Methodology, Essential Elements of Information, EEI,

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
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DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 68 IS OBSOLETE
S/N 0102-014-6601



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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# A Methodology For Determining Command, Control, and Communication (C3) Requirements For Remotely Piloted Vehicles (RPVs) and Unmanned Drone Aircraft

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS TECHNOLOGY

from the

NAVAL POSTGRADUATE SCHOOL
March 1980

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## ABSTRACT

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ACKNOWLEDGMENTS

The suggestions, comments, and support of several individuals proved extremely valuable towards the completion of this work. I would particularly like to express my deepest appreciation to:

DR Sam Parry, Thesis Advisor, for guidance and patience.

LTC Ed Kelleher, Thesis Advisor, for guidance and editorial patience.

LTC Edward Crankshaw, CAP, Fort Ord Professional Development Department, for assistance with resource materials and editorial comments.

Mr. John Woods, MOS Library, Fort Ord, for assistance with resource materials.

Ms. Kathryn D. Hogue for editorial proofing and comments.

I also wish to thank my wife, Sharon and our children, Lisa and Scott, for their support and self-sacrifice during this particularly arduous period.

# CHAPTER I. INTRODUCTION

This work describes and illustrates a methodology for determining command, control, and communications (C3) requirements for remotely piloted aircraft (RPA). The effort has been restricted to airborne platforms and the investigation of the following issues:

1. Manned versus Unmanned Aircraft
2. Unmanned Aircraft as Weapon Delivery Platform
3. Unmanned Aircraft as RECON/DESIGNATION Platform
4. C3 Requirements for Unmanned Aircraft
5. Unmanned Aircraft System Cost Effectiveness

The initial portion of the article discusses some of the factors contributing to the current renewed interest in unmanned aircraft as related to future combat environments and the threat which may be involved at the initiation of hostilities. This is followed by an analysis of the issues, a description of a methodology for determining C3 requirements for unmanned aircraft and finally by a summary concerning the issue of system cost effectiveness.

## CHAPTER II. BACKGROUND OF UNMANNED AIRCRAFT

During the past few years the term "remotely piloted vehicle" (RPV) has been used as a descriptor for unmanned aircraft which have a human operator that monitors and controls their missions, while the term "drone" has been used to describe unmanned aircraft whose missions were preprogrammed. The critical feature is not whether these vehicles are classified as RPV or drone since such classifications are strictly dependent on the desired mission tasks; but rather that they are unmanned, and thus, may cost and operate differently than their manned aircraft counterparts. During the remainder of this article the term "unmanned aircraft" will be used in a very general way to describe both RPV and drone type aircraft which are unmanned and perform either one-way or two-way missions as remotely piloted aircraft (RPA).

Unlike nuclear weapons and intercontinental ballistic missiles (ICBMs), unmanned aircraft are not a sudden and dramatic technical breakthrough. They are a system whose time has come because of a fortunate confluence of advances in technology which can provide a new military system capable of matching the trends of modern warfare. Norman Augustine, Under Secretary of the Army, described these trends as a high rate of attrition in combat, vast Soviet numerical superiority in

weapons, and the critical role of tactical and technical surprise.[1].

While the idea of a television-equipped radio-controlled airplane dates back to 1924 in a Hugo Gernsbeck magazine article [2], the actual first use in World War II had poor results. Technology was not adequate to provide the performance, accuracy, and reliability needed for an effective RPA.

Vietnam saw extensive use of Firebee target drones flying preprogrammed reconnaissance missions. The performance, reliability, and survivability of these drones indicated that the RPA was practical. In the 1973 Arab-Israeli war, the improvised use of RPA demonstrated a potential counter to the devastating capability of modern air defense systems.[3].

Unmanned aircraft can be assigned a wide variety of missions. These can be considered in terms of mission intent. In the classical manner missions may be viewed as being either strategic or tactical in nature. In either case the missions may or may not include ordnance delivery.

Modern technology has enabled unmanned aircraft to perform reconnaissance, target designation, attack, and electronic warfare missions. When used for reconnaissance and attack missions, target acquisition, atmospheric research and laser designation, the RPA's versatility in size and performance make them an alternative to

manned aircraft in many situations.

There is a rather clear division of unmanned aircraft into two classes: high and low-performance. High-performance RPA are adaptations or derivatives of present subsonic and supersonic air target drones. These RPA can perform reconnaissance, target designation, target attack, and electronic warfare missions which in the past have been the exclusive domain of manned aircraft.

High-performance RPA are a highly desirable alternative to manned aircraft when:

1. the tactical situation requires more aircraft than are available (or can be afforded) from the manned aircraft fleet;

2. the probability of loss of the mission aircraft is greater than can be accepted; and/or

3. the mission can be executed by RPA at a lower total system cost than by a manned aircraft.

The low-performance, or "mini RPA" is a high technology military version of the model airplane. While the ultimate uses of this RPA remain to be determined, its many possibilities are exciting and offer opportunities to increase the combat effectiveness of our ground, naval, and air force at a very modest cost.[4]. Depending upon mission and configuration,

mini-RPA can provide an abundant, low cost alternative to fixed and rotary wing aircraft for reconnaissance, target acquisition and designation, and electronic warfare operations. In an attack mode, as a kamikaze precision guided munition, they may be used to supplement or replace guided bombs, air-to-surface and surface-to-surface missiles, and cannon-launched projectiles.[5].

Three fundamental factors have helped to focus the interest now seen in the possible military use of the RPA:

1. The increasing lethality of anti-aircraft defenses.

2. The present level of aircraft and equipment costs.

3. The technological advances of electronic and avionic equipment.

The RPA offers the potential for counteracting enemy ground-to-air defense systems while reducing personnel losses.

## CHAPTER III. ANALYSIS OF THE ISSUES

The choices facing decision-makers concerning weapons systems that may help shape the the roles that U. S. forces play in future confrontations are complex and critical. Regardless of the final arsenal assembled, at the time hostilities are initiated, aspects of command, control, and communications (C3) will impact the total capabilities of the U. S. forces.

For example; in Europe, choices of this nature depend on an assessment not only of costs, but also of the military capabilities of the allies and the Warsaw Pact. Assessment of allied capabilities is necessary because the relationship among NATO forces in the Central Region is such that a weakness in one sector of the front could threaten the defense of the entire front.

### A. FIREPOWER THREAT IN EUROPE

Firepower and maneuver are two of the essential elements of modern ground combat. Although maneuver brings firepower to bear on enemy targets, it is the application of firepower that destroys those targets.

Direct fire ground forces almost certainly can deliver more sustained firepower and destroy enemy

armored formations more effectively than close air support forces of equal cost. However, ground forces lack the capability of airborne firepower assets to cover long distances quickly to meet an attack or to carry the battle to the enemy.

Firepower assets can also be defined in terms of how quickly they can be brought to bear in the European Central Region. "Immediately available assets" are those attached to active ground and air forces located in Central Europe. "Early reinforcements" can be described as those ground and air units that can be sent to the Central region in a few days or a week---for example, allied ready reserve units in Europe, U. S. tactical air squadrons based in the United States, and airlifted U. S. ground forces whose heavy equipment is stored in Europe. "Later reinforcements," such as U. S. ground forces travelling by sea, are those that take weeks to complete the move to Europe.

The United States and its NATO allies appear to be at a numerical disadvantage in immediately available ground force firepower weapons when compared to the Warsaw Pact. This apparent disparity may be exaggerated by differences in the quality, doctrine, roles, and organization of NATO and Warsaw Pact forces. Whether the overall balance is unfavorable or not, however, Warsaw Pact forces could possibly gain a significant local advantage over NATO by massing for an attack, thus

creating a need for quick reinforcements.

Although the Pact's initial numerical advantage seems to be widely accepted, factors other than numbers of weapons in units also affect the balance of firepower capabilities between NATO and the Warsaw Pact. One such factor is the quality of arms. For example, not only do the Soviets have more artillery, but several of their weapons have greater ranges and rates of fire than NATO artillery.[6]. On the other hand, almost all NATO artillery in Europe is self-propelled and has some armor plating, making it less vulnerable to enemy fire than the bulk of Soviet artillery, which lacks crew protection.

Doctrine also affects the firepower balance. The Soviets emphasize conducting offensive operations at the earliest possible moment in the conflict, and they stress achieving fire superiority over the enemy. Soviet doctrine for attaining this superiority emphasizes massing large numbers of artillery at the breakthrough point, conducting a prolonged, intense artillery barrage to destroy enemy strongpoints and disrupt enemy control and reinforcement, and then attacking immediately with tanks and motorized infantry along the path prepared by the artillery barrage.[7]. This doctrine for artillery fire and the less sophisticated Pact ammunition make it necessary for the Pact to use large amounts of artillery. These guns deliver an enormous volume of fire on large areas of the battlefield rather than on particular

targets.

NATO doctrine, on the other hand, emphasizes using artillery to attack particular battlefield targets that threaten ground forces. The superior accuracy and lethality of NATO artillery weapons is expected to permit these targets to be destroyed without employing prolonged, disruptive fire over large areas of the battlefield.

Some types of weapons---especially antitank guided munitions (ATGMs)---appear particularly suited to defensive operations, while other weapons---especially tanks---are often regarded as most effective for offensive maneuvers. Thus in assessing Soviet and NATO firepower capabilities, it may be misleading to rely solely on direct comparisons of their tanks, without considering that the defensive advantages of NATO antitank missiles may partially compensate for Soviet advantages in numbers of tanks.

A fourth factor in the firepower balance is the organization of firepower assets. The Warsaw Pact's firepower assets are organized to attack or defend in a depth of two or three ranks or "echelons." Consequently, only a portion of the entire force is directly engaged with enemy forces at any one time. When units of the first echelon have become ineffective through combat losses, they are replaced by units from the second echelon. The second echelons take up the fight

until they, in turn, need replacement. Units pulled back to the rear are rebuilt and made ready to rejoin the battle. This "unit replacement" approach permits Warsaw Pact forces to engage in continuous ground combat while attempting to maintain a fairly high level of effectiveness.

In contrast, rather than pulling entire units out of the line, NATO ground forces are expected to replace combat losses on an individual and continuous basis. Thus, a sizeable portion of NATO's assets are retained in maintenance and war reserve stocks.[8].

A fifth important factor affecting the firepower balance is mobilization time. The immediate numerical balance of principal firepower assets is unfavorable to NATO. A short mobilization time would make the numerical balance even more unfavorable, since the Soviets can deploy forces over land from the Soviet Union faster than the United States can deploy forces from North America.

These factors of quality, weapons mix, doctrine, organization and available mobilization time clearly affect the balance of firepower capabilities, though it is difficult to assess their precise impact. It is clear to the author, however, that conclusions about NATO firepower capabilities based on numerical comparisons of weapons in units should be qualified to account for these factors.

Nevertheless, the availability of such extensive

Warsaw Pact ground force firepower assets in Europe, especially when coupled with the emphasis of Soviet military doctrine on offensive operations [9], should prompt concern. This concern is heightened by the possibility that a Pact attack on Western Europe could occur with very little warning, could be aimed at rapidly overwhelming NATO defenses in a short, very intense war, and could be conducted initially with forces in Eastern Europe, without reinforcements. These Warsaw Pact forces probably would mass against relatively weak points in NATO's defenses and could achieve large concentrations of force anywhere along the East-West border. Thus, it is possible that---whatever the overall balance---if NATO has little time to mobilize, its firepower capabilities may be inadequate at the point of attack.

In addition to firepower balance, it is necessary to understand the role of the manned aircraft in the Central European scenario before the value of the RPA can be considered.

## B. USE OF MANNED AIRCRAFT

Airborne firepower, with its ability to concentrate quickly, may partly compensate for deficiencies in ground force firepower, depending on how it is organized and applied. It is clear to the author that the allies and the United States have different

approaches to the use of airborne firepower, although it is difficult to say which approach is more effective. Currently, the NATO allies have essentially no specialized attack helicopter forces. They use multimission aircraft for firepower support of ground troops, while the United States appears to increasingly depend on specialized aircraft for ground attack missions.

The European NATO allies not only lack the number and sophisticated kinds of U. S. attack helicopter assets, but they also possibly plan to use the assets they do have differently. In contrast to the expected U. S. practice of attaching some armed helicopters to ground force divisions, the European allies appear to prefer to use the helicopters as a corps reserve force. The United States would probably use armed helicopters to harass or delay an attacking force or to reinforce a defensive position from which ground forces have been transferred to meet a threat elsewhere. It appears to the author that the allies would prefer to hold their helicopters in reserve and commit them only when an enemy breakthrough could not be stopped by ground forces. Indeed, some allies, notably the British, do not believe in using attack helicopters near the forward line of own troops (FLOT).[10]. Although the allied approach seems to be in keeping with the small size and light armament of their current helicopter forces, it would appear to reduce the potential effect of these forces on the initial battle,

where their firepower may well be of greatest value.

The allies' close air support capabilities are more extensive than their attack helicopter capabilities, but the rationale behind their choice of weapons is similar. The United States assets appear to the author to be increasingly emphasizing the destruction of individual tanks with gun and guided missile fire from slow-flying aircraft operating from behind friendly forces. The allies, by contrast, seem to have chosen not to invest in specialized aircraft for this type of combat; they seem to prefer to deliver scatterable area-type weapons at very high speeds and low altitudes at some distance behind enemy lines, overflying enemy forces and defenses in the process. In addition, unlike the United States, most allies do not stress the role of the Forward Air Controller in coordinating air strikes with ground force operations. Thus, many of the allies lack both the personnel and the practice required for close coordination of air strikes and ground force operations. What the allies call "close air support," the United States would consider "battlefield interdiction"---that is, disrupting enemy troop movements several kilometers beyond the FLOT, with little coordination between friendly air and ground forces.

In practice, there are authors who hypothesize that these doctrinal and procedural differences between the United States and the NATO allies do not significantly affect the conduct of military operations. Despite the

apparent procedural differences, U. S. close air support aircraft could probably be effectively used to reinforce allied ground forces. Still, if the United States wished to emphasize its ability to provide this kind of flexible air support to the allies, it should strive to better coordinate close air support procedures and doctrine, in order to ensure maximum C3 effectiveness of U. S. support.

Like the allies, the United States is planning improvements in the quality, rather than a dramatic increase in the number, of its artillery pieces. The U. S. is pursuing its objective of increasing the range, volume of fire, and lethality of its artillery through a number of programs, many of which involve only small near-term costs. These include fitting longer gun tubes to existing 155 mm and eight inch howitzers; procuring rocket-assisted projectiles for greater range; developing and procuring improved conventional munitions that scatter bomblets over wide areas; developing laser-guided artillery shells that can accurately strike tanks and other point targets; and developing imoroved artillery-locating radars and a computerized fire-support coordination capability. Finally as a complement to its cannon artillery, the United States is also developing the General Support Rocket System---a multiple rocket launcher capable of delivering a high volume of fire very rapidly. An accelerated development schedule may make

this system available by the early 1980s.

The United States now has an inventory of narrow-bodied rocket- and machine gun-armed Cobra helicopters which constitute an integral part of the firepower of almost all U. S. Army divisions. Their sole purpose is delivering ordnance on battlefield targets. These aircraft are intended to fly close to the ground, using terrain and vegetation to conceal them from enemy view and attack. With the assistance of Scout helicopters flying with similar tactics, they locate enemy ground force targets and climb from their concealed positions only long enough to fire weapons at the target before descending and moving on under cover.

The Army is in the midst of a program to convert almost 700 existing Cobra helicopters to carry eight TOW ATGMs, and to procure 305 identically equipped new Cobras.[11]. This program will provide U. S. forces with a highly mobile antitank capability. With the addition of limited night-vision capability, this antitank force will have an improved capability to fight in darkness.

There are two alleged problems with the Cobra/TOW. First, as a modified aircraft of the Vietnam era, it is said to lack sufficient armor protection for a European battlefield. Second, because the aircraft must emerge from cover for up to 15 seconds in order to visually guide its TOW missile to the target, it is said to be vulnerable to enemy detection and destruction. To alleviate those

problems, the Army is developing the Advanced Attack Helicopter (AAH), of which 536 are to be built between 1981 and 1987, at a cost of $5.9 million each. The total cost of that program will be about $4.1 billion. The Cobra/TOW will complement this fleet.

The AAH will have greater armor protection and redundant controls to improve its chances of surviving if hit. Most importantly, it will fire the Hellfire laser-guided missile, which follows a laser beam---directed on a target by a ground observer, another aircraft, or by the AAH itself--and strikes its enemy target accurately. When the enemy target is designated by a ground observer or another aircraft, the AAH will be able to fire the missile from a completely concealed position, thus reducing its chances of being attacked by the enemy.

Despite these advantages, the AAH is not without problems. The ground laser designators are, of course, vulnerable to suppressing fire, and they may very well lack adequate time to move into position if an attack comes with little warning. The Scout helicopters that designate targets for the AAH must expose themselves during the entire missile flight; lacking armor protection or defensive armament, they are as vulnerable to destruction as the AAH itself. The AAH can, of course, designate targets for its own missiles without the assistance of Scout helicopters, but its resulting exposure reduces the advantage of the Hellfire missile.

If the AAH is struck by one or two bullets---the kind of small-arms threat to aircraft experienced in Vietnam---its armor would protect it. The most severe threats to the attack helicopter in Europe are, however, the Soviet radar-directed ZSU 23 mm four-barrelled anti-aircraft gun, the SA-7 hand-held anti-aircraft missile, and SA-8 and SA-9 surface-to-air missiles. The ZSU-23 delivers a very high volume of fire; if the AAH is struck by one of its volleys or by one of the anti-aircraft missiles, the helicopter will probably be destroyed.

Close air support aircraft constitute a second type of airborne firepower assets. The U. S. defines close air support as the delivery of air weapons in close coordination with ground force movements, which implies the presence of a Forward Air Controller for coordination. While the United States currently performs close air support with A-7D attack aircraft, supplemented by F-4s and all-weather capable F-111 fighter-bomber aircraft as needed and available, the Air Force is introducing an aircraft designed solely for close air support---the A-10. The A-10 is designed to be a simple rugged aircraft with a large weapons capacity and antitank capability. It carries a 30 mm cannon, which fires armor-piercing ammunition at a very high rate, and as many as six Maverick guided missiles. Because of its large size and slow speed, the aircraft can best survive combat by avoiding enemy air defenses. Its primary tactic is therefore to fly

low behind friendly forces, "popping up" only long enough to strike an enemy target with the gun or a missile. Despite some vulnerabilities, the Army and the Air Force believe that the A-10 can survive combat if it uses appropriate tactics and is assisted by other aircraft that attack enemy air defenses.

The use of U. S. attack helicopters to supplement allied firepower capabilities would also raise coordination problems. U. S. attack helicopters currently operate as an extension of, and in close coordination with, ground forces. The difficulties of achieving close coordination between U. S. helicopters and allied ground forces would be exacerbated by the language and procedural differences of the other NATO forces.

The principal constraints on the utility of the A-10 in Europe are its lack of a night and adverse-weather capability, the limited number of aircraft planned for deployment to Europe and a shortage of aircraft shelters large enough to accommodate the A-10. These constraints become significant when considered in light of the Pact's ability to choose the time and weather in which to attack. If there were little warning of attack, NATO would need more aerial antitank firepower than in a longer warning scenario.

The use of U. S. aircraft to delay enemy attacks on allied forces and to destroy enemy tanks and

armored vehicles could help the allies hold their defensive positions until ground force reinforcements could be shifted from other sectors of the Central Front or shipped from the United States.

The principal disadvantage of this option is that, while manned aircraft can supplement ground forces, they cannot substitute for them: they can neither deliver a sustained volume of fire equivalent to ground forces of equal cost nor hold or take territory. Those factors make the kind of close air support reinforcement described here a temporary rather than a long-term substitute for ground forces.

The analysis of the manned versus unmanned aircraft issue underscores the previously discussed problems related to aerial tactical warfare while attempting to show that remotely piloted aircraft (RPA) could possibly be a desirable alternative to manned aircraft when the tactical situation requires more aircraft than are available (or can be afforded) in the manned aircraft fleet; the probability of loss of the mission aircraft and pilot is greater than can be accepted; and/or the mission can be executed at a lower total system cost than by a manned aircraft.

Through the years, manned military aircraft have steadily grown in complexity and cost. A major factor contributing to both complexity and cost is the need for providing the pilot with comprehensive information

and personal protection. In fact, carrying the human operator onboard compounds the "costs" in that it limits the aircraft's maneuverability. Pilots are valuable personnel. It has become increasingly important on military, economic, and political grounds to protect their lives and prevent their capture. Even though one-way tactical missions would often be of value, they are unassignable in terms of the high cost of pilot experience, to say nothing of the value of the human life in our cultural context.

Weapon systems can be fully automated so that once released they perform as programmed. However, intelligence systems are not perfect, and it is difficult to anticipate the exigencies which may be encountered during a mission. With greater destructive power comes greater responsibility for maintaining human control over the weapon until the moment of its final disposition. The value of weaponry is greatly enhanced by including human intelligence in the operational system. The use of RPA allows the human operator to be in a position to monitor or assume direct control, yet be removed from the weapon platform.

Thinking along these lines, one may ask the following questions: If we must or want to use an air vehicle, why must we also have a human operator in it? How much of the time, (i.e., during what fraction of a combat sortie), is the human operator really needed? The

onboard pilot is only needed when the operator has to "see" something---discriminate and decide.

A growing problem in tactical warfare operations (and, the author suspects that analogous ones exist for other kinds of operations) the improvement of accuracy in ordnance delivery in the face of improvements to enemy air defenses, while decreasing costs and air-crew losses?

The essence of the solution, i.e., reducing the loss of manned aircraft and crews, is the real-time utilization of man's inherent capabilities of discrimination and decision by means which let the operator stay remote from the actual firing zone. The RPA should be thought of as a guidance and control system. It is a guidance capability providing for substantial real-time tactical decision-making essentially as presently done by pilots in manned aircraft. That is what is meant by "Piloted" in "RPA." RPA can be two-way or one-way vehicles. They can carry warheads or only reconnaissance (RECCE) or communications gear. They are not necessarily drones---which may or may not be remotely controlled, but are not remotely piloted. The RPA is a standoff guidance system. It provides the capability and the opportunity to preserve and exploit the operator's unique real-time abilities without requiring that the operator be exposed to the most lethal environments of tactical aerial warfare. That is what is meant by "man-in-the-loop."

In comparison with manned aircraft, tactical RPA offer the following potential advantages:

1. operate much closer to the target because of reduced size and risk to the operator;

2. present a smaller target to defending antiaircraft artillery (AAA) and surface-to-air missiles (SAMs);

3. delay weapon release until they are very close to and very sure of the desired target;

4. do not risk pilot loss.

In general, the RPA can find profitable application wherever enemy air defenses can be expected to exact high loss rates; whenever the attacker cannot afford to miss an aim point; whenever the target or target complex does not require a large weight of ordnance over a large area; whenever the human body cannot tolerate prescribed maneuvers or endure other flight conditions, and whenever human discrimination, judgment, and decision must enter the lethal environments of an area defended by modern anti-air weapons.[12].

## C. ANALYSIS OF UNMANNED AIRCRAFT AS WEAPON DELIVERY PLATFORM

Survivability of fixed and rotary-wing aircraft, both as individual mission aircraft and as essential organizational components of a modern integrated air-ground force, is a critical issue today. For the past decade the ability of ground air-defense systems to shoot down aircraft has been increasing at a greater rate than has the survival ability of manned aircraft. Unless this trend is reversed, tactical air and air-mobile forces will no longer be able to make a major and sustained contribution to winning the battle on the ground.

As individual aircraft, RPA have a higher probability of surviving a combat mission than do larger, manned aircraft. All "observable signatures"-radar, infrared, visual, and aural---are much lower for RPA than for manned aircraft suitable for the same tactical missions.[13].

In the case of mini RPA, these signatures, as seen by the hostile defense, approach the vanishing point. RPA present a much smaller vulnerable target to be hit by an impact munition or the fragments of a proximity-fused munition---a major gain in aircraft survivability.

This RPA survivability, if combined with very large numbers of them, could give the air unit commander freedom to undertake missions considered desirable or essential but too hazardous to risk a manned aircraft. It is inevitable that a high and sustained attrition rate will have a negative influence on the operational

decisions of the commander of a manned aircraft unit. In an effort to preserve assigned forces, when the commander has any choice on which targets to attack with manned aircraft, that commander will favor those with a lower attrition rate even if of lesser value; or will adopt mission-execution modes which will reduce the unit's attrition rate although the effectiveness of the mission may suffer.

With only a limited number of costly and (at least in the near term) irreplaceable aircraft and pilots, operational caution will be a powerful factor in a commander's decisions. The Israelis have already faced this issue. Their former Chief of Staff, David Elazar, has stated that close air support has been dropped as an air mission because it has become too costly for the results achieved.[14].

Tactical utilization of RPA could include strike missions conducted in close support of ship or ground forces. The targets will possibly be well known in position, highly protected and of high value. Here, the RPA may become the weapon, by carrying ordnance directly onto the target, and be used to destroy SAM sites, bridges, individual ships, factories, and so forth. Alternatively, the RPA could be used for delivering ordnance with a recovery maneuver so as to decrease the weapon system cost through re-use, or serve as a target designator for weapons to be delivered from other

aircraft or other RPA. In general, the targeting should be sufficiently specific so that the enroute route phase can be preplanned using the latest intelligence and perhaps programed into the autopilot.

Low altitude strike missions may also include the problem of finding and destroying targets of opportunity. Interdictive strike missions may be used to deny movement or rest to the enemy through intermittent strikes at staging areas, key road junctions, rail marshalling yards, and so forth. The intent of such general harassment missions might be to deliver propaganda leaflets; biological/chemical warfare weapons; chaff; jammers; to place sensors and/or mines or other conventional ordnance; or simply to cause activation of air defense systems.

RPA could possibly be flown in sequence and/or formation in such a way as to reveal and deplete the enemy's defense capability. A second strike force of manned aircraft could possibly be timed to appear just when the enemy's responsive capability has been temporarily exhausted. RPA may be used in spoofing; that is, to simulate a bomber or other type of aircraft through the use of an appropriate transponder or radar cross-section reflectors. Used in force, remotely piloted aircraft may simulate an air umbrella over an imaginary fleet of ships, thus confusing enemy reconnaissance; or fly over enemy territory in ways so as to mislead the enemy commander as to

the actual direction of the attack.

If tactical air and air-mobile forces are to carry out their doctrinal missions, the effectiveness of hostile ground-to-air defenses must be reduced through intense, sustained, lethal, and nonlethal air-defense-suppression operations. At the present, the United States' primary means are attacks launched from manned aircraft. This mission deliberately pits friendly manned aircraft against the enemy system designed to shoot them down, which historically results in high attrition rates.

The RPA offers the potential of becoming the instrument to challenge and possibly defeat an opposing enemy air defense system. RPA could be built in large quantities and operated in large numbers in the enemy's airspace so as to force the enemy air defense systems into a higher level of electromagnetic radiation and shooting. This could cause an increased expenditure of munitions by the enemy air defense units and reveal their positions, thus subjecting them to attack.

Such a deliberate and intense confrontation between RPA and hostile air defenses should quickly reduce the number and effectiveness of enemy air defense units and make the surviving defenders gun-shy, thus permitting both manned and RPA to execute their other combat missions with greater freedom of action, in a more effective way, and with lower attrition rates.

## D. ANALYSIS OF UNMANNED AIRCRAFT AS RECON/DESIGNATION PLATFORM

To successfully defeat the enemy, the commander of today must be able to recognize enemy intentions and take positive action at the earliest possible time. Senior commanders must:

1. see the battlefield
2. direct the intelligence effort,
3. develop a concept of operations,
4. allocate assets,
5. sustain the forces, and
6. plan and execute centralized operations for effective C3 that will interface the appropriate battlefield systems.

It is not by coincidence that "seeing" the battlefield is listed first. Only by "seeing" the battlefield to the depth necessary to identify and track the movement of the enemy second- and third-echelon forces can the commanders perform the other functions expected of them, especially at the right time and place. The requirement for the commanders to "see" the battlefield has resulted in an increase in the amount of information required by the

commander and the organic staff.

One of the major requirements for a tactical command and control (C2) system is the availability of accurate, real-time position information on friendly personnel, vehicles, and aircraft. This is especially true when operating during the hours of darkness and in those parts of the world that are devoid of prominent terrain features. The RPA could possibly provide a means of collecting, transmitting and/or retransmitting vital information to organic staff elements so that data and information can be provided to the appropriate commander in sufficient time to allow decisions to be rendered that could significantly influence the combat situation at some point in the future.

RPA may be assigned to surveillance missions to cover particular battlefields or areas of ocean. They may provide early warning against land, sea, or air attacks, monitor and track enemy movements, serve to identify any modification of enemy held terrain through use of repetitive video recording or photography in the visual range, infrared, ultraviolet, or combination thereof or through the use of moving target indicating (MTI) radar. Search and rescue missions might benefit from the use of RPA. Here,for example the RPA might be used to drop an encoded transponder, critical supplies, or even to provide urgently required defensive materiels such as ammunition and anti-personnel mines after detecting and locating a

surrounded ground unit.

The RPA may provide unmanned target acquisition, reconnaissance, and adjustment of artillery fires, as well as target designation and damage assessment forward of the line of contact in support of combat elements. Depending on the tactical situation and the priorities established by supported commanders, the RPA system could be used to enhance the delivery of cannon and general support rocket fires for close support, counterfire, suppression of enemy air defense (SEAD) and area denial utilizing scatterable mines. In addition the RPA may also be used to provide data to division artillery for the update during or following nuclear exchanges on the battlefield.

The RPA as a reconnaissance and target acquisition/designation system will cue, be cued by, and complement other target acquisition, reconnaissance and surveillance systems, to include manned aircraft. Imagery from the RPA sensor system should provide sufficient resolution to detect, classify, recognize, and locate hostile field artillery and air defense weapons (to include those with nuclear delivery capability), wheeled or tracked vehicles, personnel comprising platoon or larger sized units, structures and terrain capable of containing command posts, supply points; to make damage assessments; and to update the nuclear targets.

Soviet exploitation of their own technological developments has produced increasingly strong forward battle area surface-to-air defenses and, at the same time, strengthened the need for U. S. combat support to help offset the massive enemy ground force fire power potential. The enemy tactical air defense system, unless countered, will seriously decrease the capability of air forces to provide the required fire support to friendly ground forces. Presumably, the latter condition is a good indicative of the enemy's concern for the effect of that fire power on their own forces. Three possible responses to permit delivery of fire support in the face of highly effective, mobile, and proliferated air defenses are to employ standoff weapons to alleviate the need for penetration in providing aerial fire support; reduce the air defense effectiveness (decoys, jamming, harassment, etc.); or destroy the defenses. To successfully deliver weapons against ground targets (by whatever means---manned aircraft, RPA, or standoff missiles), it is necessary to accomplish a variety of supporting functions such as reconnaissance, surveillance, target development, identification, and acquisition, laser designation for guided weapons, fire adjustment, and strike control.[15].

This diverse set of missions can be satisfied by a relatively small number of functional capabilities: observation of the area or item of

interest with an appropriate sensor (i. e., one that can provide the kind and quality of data required by the mission), determination of target position, and provision of a means of fire control and adjustment. The benefits from applying the human's memory, reasoning, and decision-making capacity in these processes is clear. In attempting to provide these capabilities, there are advantages to be gained in operating from an elevated platform close to the objective area, with whatever specific capabilities might be required to accomplish the task. This means employing an appropriate set of vehicles and operational concepts that satisfies the mission requirements within tolerable cost bounds. The developing image of the technologically advanced battlefield--large numbers of mobile, hard target elements that must be located precisely and struck accurately---combined with the environmental constraints of poor weather and rough terrain indicate that a low, slow, maneuverable platform is preferred.[16]. The increasingly hostile environment over and beyond the FLOT caused by the growing surface-to-air defense system effectiveness makes the use of manned aircraft systems in this role extremely expensive in both personnel losses and dollar cost.

The employment of RPA systems for combat area surveillance, target acquisition, and strike control against battlefield targets such as armor, artillery, and ground-to-air defenses could help to

offset the serious threat resulting from the incorporation of advanced technology by the enemy. For these applications, the motivation for considering RPA systems derives from the ever-widening gap between the firepower of the Warsaw Pact ground forces and that of the NATO defenders, coupled with the strengthening protective ground-to-air shield covering the Pact armored assault forces. Consequently, in this context, the introduction of RPA systems should be viewed as a complement and supplement to manned surveillance (i.e., forward air controller) and strike aircraft in a total force context, and as a hedge to cover those situations that will require the Air Force to provide vital supporting fires to ground forces, even though the use of conventional manned aircraft might lead to grievous losses.

Many mission functions, if they are to be performed by unmanned aircraft at all, require transmission of data in real- (or near-real-) time over a data link from the vehicle to a remote control station. Thus, a new potential vulnerability (the data link itself) is added to the tactical air-ground strike system. This problem is one of a considerably different character than has been faced before by tactical strike force planners and operators. In this sense, the successful operation of the data link is not a militarily useful end product in and of itself. Presumably, however, a functioning data link is a requisite component of the RPA system. Thus, it would

seem appropriate to measure the impact of the performance of the data link (i.e., the resultant of the interaction of the enemy jamming effort and the level of jam resistance built into the link) in terms of the extent to which the goal of the complete system or force has been met. In the case of a data link in a target surveillance and designation RPA, as described previously, the degradation due to enemy jamming (or, conversely, the remedial value of enhanced jam resistance) could be measured in terms of the change in the number of targets detected and destroyed, or the movement in the line of contact of the ground forces being supported, for example. The key concept: provide only enough jam resistance to make the enemy's jamming system sufficiently complex and costly so that other uses of his defense budget appear more attractive.

## CHAPTER IV. C3 REQUIREMENTS FOR UNMANNED AIRCRAFT

Assessing the performance of an unmanned aircraft C3 system in a wide range of combat environments is difficult. This is due, in part to the fact that there is no general systems theory which is directly applicable to military command-control, the fact of the complexity of the military organization, and the fact that a military command system must manage in peacetime and command in combat. In addition, there is the lack of definition of what elements should be included in a consideration of a "command-control-communications system" for unmanned aircraft. For example: should intelligence sensors be included or just the information flow produced by these sensors? Much of the difficulty arises from the lack of an approach to evaluating staff organization and its operation; the effect of style of operation; the role of command-control in tactical doctrine; and the impact of military, political and social traditions. There is also the problem of evaluating the contribution which the command-control process in itself makes to the overall operation of military forces. It is an essential element of military operations, just as the logistics, training, and weapons capability are. C2 also includes the functioning of the commander as that individual formulates

decisions which will cause other elements of the military force to perform a military operation.

To win modern wars, the commander must be not only a sound military strategist and tactician, but also part engineer, scientist, psychologist and logistician. Traditionally, the commander's main focus has been the enemy. It is becoming important that the commander direct the same efforts toward organic command, control, and communications (C3) systems. The purpose of C3 is to serve the commander. Made up as it is of less-than-perfect machines, people, warfare communities, and technical disciplines, today's C3 requires the commander's detailed understanding if it is indeed to serve and not hamper operations.

C3 has been a critical ingredient in warfare since organized forces first joined in battle against other organized forces. It soon became apparent that the side which could command, control, and communicate most effectively possessed a critical advantage. In World Wars I and II, the great land battles, some covering an entire nation, and naval engagements encompassing millions of square miles of ocean provided innumerable examples of the increasing importance of C3 and the devastating effects of its absence. Adding the dimensions of air and undersea operations to warfare only serves to emphasize and further complicate C3 requirements.

Modern technology has provided the means for rapid and secure transmission of massive quantities of data and communications information to and from as well as within the battlefield area. As with any new asset, modern technological C3 requires fine tuning to emphasize its strengths and avoid pitfalls in its utilization.

A simple view of the U. S. defense posture is that it involves three necessary functions:

1. Surveillance for the purpose of assessing the capabilities and status of enemy forces;

2. U. S. forces ability to react appropriately to various levels of threat, and

3. Command and Control (C2) that integrates the surveillance and reaction functions and provides for unified defense forces.

Although there are other aspects of C2 than this simple view indicates, it is safe to conclude that the U. S. C2 capability depends significantly on the availability of information. Without vital information in response to a crisis or threat, the nation would be unable to defend itself adequately. Accordingly, a major consideration for determining requirements of command, control, and communications (C3) for unmanned aircraft systems should be to insure that the Essential

Elements of Information (EEI) necessary for decision making are known and are made explicit.

The term "essential elements of information" is not new. According to JCS PUB 1, "EEI are the critical items of information regarding the enemy and the environment needed by the commander by a particular time to relate with other available information and intelligence in order to assist in reaching a logical decision."[17]. This portion of the thesis attempts to relate the significance of EEI to C3 systems and present a methodology to determine C3 EEI for unmanned aircraft systems.

The problem of determining who needs what information and the implication of determining requirements for unmanned aircraft C3 is a primary concern. The mechanics of getting essential information from one location to another is a different and significant problem. As such, this problem has received an appropriate amount of attention at all echelons of command and will not be addressed. In particular this information flow problem has been modeled and studied in after-the-fact reconstruction and analysis of crisis situations. On the other hand, the problem of who needs what information during peacetime conditions as well as during crisis, limited war, general war or nuclear war is one which also demands attention.

A prerequisite to effective command and control is the availability of precise, accurate, and timely

information on which decisions can be based. What is often not evident in describing C3 systems however, is what types of available information are truly germane to what decisions or what levels of information, precision or timeliness are really necessary. This is of particular concern since C3 systems are, by design, information driven. As such, the fundamental criticisms for many of these C3 descriptions are the assumptions that:

1. the elements of information required by the decision maker at each echelon of C2 to handle the particular condition, as well as handle a transition to another condition, are known, and

2. the essential information is available within the required time frame.

To assume the existence of sufficient and immediately available data for decision making is a common pitfall. In spite of the fact that sophisticated sensor systems are in existence today, there is no guarantee that the EEI needed for a critical decision are available. A situation can exist in which there is absolutely no essential information available, or, no way of getting it within a reasonable time frame. A more likely situation, however, given current technology, is one where the information is available somewhere in some form, but is not immediately available to the commander.

Technological advances in sensor and communications systems have developed to the point where a command decision maker can be inundated with incoming facts and statistics, so that the decision process is impeded rather than aided. Technology has provided the means for developing hosts of sensor systems, each generally capable of contributing something to the decision task at hand. Determining the minimum EEI needed by the decision maker eliminates non-essential information and provides a means of determining the critical needs for new unmanned aircraft sensor/communications systems developments.

One technique for determining EEI is a logic tree that starts with a generic statement of the mission and the command level chosen. From this statement, a set of Minimum Essential Functional Tasks (MEFTs) must be developed that describes the actions or procedures for the command level and assigned mission. Each MEFT can then be logically subdivided into more definitive subtasks. The process must be continued until a task element level occurs such that the task reached is limited to one specific subject which calls for only one specific action.

When the MEFTs correctly represent the minimum-functional tasks, and the factor analysis is properly carried out, the pieces of information may then be considered EEI. Because EEI are developed from MEFTs, the

need for care in defining the MEFIs is obvious. If MEFIs are not essential to the mission, the resulting factored information will contain irrelevant or redundant elements.

The factoring process can be viewed as a phased development. A minimum of three phases would be required to fully develop unmanned aircraft EEI. However, the methodology proposed by this thesis goes beyond simply developing the EEI. The methodology is extended in order to provide connectivity to the description of other interfaces in C3 systems. The proposed phased approach is described below:

1. Phase I

The first phase consists of taking the subtasks under each MEFI and essentially asking the question, "what is the minimum information required" to answer the subtask. For broad subtasks, this would result in a requirement to further subdivide until a specific question level or basic task element is identified. These are in turn factored down to basic information elements. The end point for any given factoring chain is one or more data elements, the EEI.

Factoring all subtasks under all MEFIs would result in a series of factoring chains. Each chain must be developed independently in order to gain insight into the requirement for individual data elements. The factoring chains must be

reviewed to determine commonality in requirements for the same data elements.

2. Phase II

Given the EEI, Phase II is an evaluation of the questions; 1) How accurately must the EEI be known, 2) How timely (from event to commander) should the delivery of the EEI be and 3) How often should the EEI be updated or revalidated ?

3. Phase III

The third phase entails consideration of how many EEI in total there might be given in a real world worst-case mission. This phase would involve taking the number of EEI per force element, target or event in the actual situation anticipated.

4. Phase IV

Phase IV is the initial validation of the factoring process. One way to use and test the EEI is to place them in an appropriate command level involved with major operational exercises or war games. The operational exercise or war game training should cover all theaters of operation for all conditions of readiness and states of

transition. If the EEI were developed for a corps commander, then that commander would be the only one who could decide what information is needed to accomplish assigned missions. The corps commander is the decision maker in the war game exercise and as such must decide what the EEI are.

5. Phase V

Once Phases I-IV have been accomplished from the lowest command level to the National Command Authority (NCA) it is necessary to integrate and determine what is common and what is unique. The data bases at each level can be combined and purged; procedures, standard operating procedures (SOPs), strategies and doctrine can be developed to interface and provide for the optimum utilization of the EEI.

6. Phase VI

A final phase could be one which would provide for EEI integration with allied forces in NATO. This phase would require additional analysis and would probably generate a new set of EEI based upon new mission requirements and interfaces.

The entire process is not as difficult as it may seem at first glance. Most units have some general concept of

their particular EEI, but they may or may not use or validate the EEI. Considerable time and effort is spent on developing models and war games throughout the military, private industry, and the academic community. What would be needed to systematically determine EEI for unmanned aircraft is orchestration. The promulgation of service compatible guidelines, goals and objectives would be necessary. Progress would have to be measured. The result of such effort could have far reaching implications for the following:

1. evaluating the collection capabilities supporting the commander,
2. sizing Automated Information Handling Systems,
3. prioritizing Information Flow in Capacity Limited Communications Channels or Message Centers,
4. modeling a specific C3 system or systems, and
5. development proposals for C3 systems and related systems.

If a structured analysis like factoring was performed the ability to understand and determine requirements for unmanned aircraft C3 systems and problems would be enhanced. The information needs of the unmanned aircraft C3 system would be made explicit and hence subject

to criticism and improvement.

An illustration of the methodology is contained in Appendix A.

# CHAPTER V. SUMMARY AND CONCLUSIONS

## A. SUMMARY

In comparison with manned aircraft, tactical remotely piloted aircraft are expected to produce the following advantages (as previously described):

1. a remotely piloted aircraft could attack much closer in,
2. would present much less target area to defending AAA and SAMs,
3. could delay weapon release until very close (and very sure),
4. could deliver ordnance directly to the target, and
5. would significantly reduce any risk of pilot loss.

To ensure a successful RPA program the following are required:

1. lowest possible cost of ownership.
2. simple in concept.
3. no high-risk technology.

Warsaw pact Forces will be led and employed according to Soviet operational doctrine which calls for offensive operations with highly mobile, deeply echeloned,

and numerically superior land forces, supported by air and sea power. Terrain and visibility obstruction (such as fog, smoke, darkness, adverse weather, etc.) will generally limit ground observers to a range of 3-5 kilometers beyond the FLOT for observation and identification of hostile forces.

This massive enemy threat indicates a requirement that the maximum number of forces be detected, identified, and destroyed prior to engaging friendly forces. Destruction of enemy forces can be accomplished with artillery, attack helicopters, and close air support, if those targets can be identified and located with sufficient accuracy for timely targeting.

The RPA could help overcome operational deficiencies by providing the maneuver commander and fire support coordinator with real-time combat information, accurate target location, and an observed target engagement capability beyond the ground line of sight. Such information will enable more timely repositioning of forces, more effective utilization of conventional munitions, and provide a means of target selection and designation for precision guided munitions (PGMs) not currently available to the ground forces, without subjecting manned aircraft to the very formidable air defense threat.

## B. CONCLUSIONS

1. At the discretion of the ground force commander, the enemy forces may be kept under observation utilizing the RPA, taken under conventional artillery fire, engaged by TAC Air, or be designated for attack by PGMs, if so equipped.

2. The RPA system must contain a jam resistant data link and communications interface with information systems for tactical command and fire control.

3. An RPA system with a real-time data transmission (to include relay/retransmission) capability can overcome line of sight and range limitations imposed on ground sensors in meeting the commander's need for a reconnaissance and target acquisition asset.

4. The RPA can provide improved operational effectiveness by giving the ground commander an "over the hill" look and target engagement capability not currently possessed, by materially increasing the real-time intelligence and combat information gathering capability.

5. RPA systems can significantly decrease nonproductive ammunition expenditures by providing target location and burst correction information that would provide sufficient accuracy to allow supporting artillery to fire for effect after minimal adjustment.

6. Interoperability with NATO Air Defense and U. S. Air

Defense must be insured for developing RPA systems.

The Vietnam experience has been updated by more recent Israeli applications of U. S. tactics and equipment to more densely deployed and modern defenses in the Middle-East in October of 1973. U. S. superiority in air crew capabilities and more sophisticated offense-oriented weapons and tactics are probably offset to some extent by greater Soviet emphasis on ground-to-air defense, especially in Central Europe. Soviet measures such as sensor redundancy, frequency, diversity, mobility, hardness, emission control, and sheer numbers limit the effects of most forms of defense suppression. The Soviets are also expected to have superior intelligence of U. S. and NATO offensive and defensive systems. Combining the advantages of taking the initiative and of tight security with good intelligence offers the Soviets opportunities for both tactical and technical surprise.

Whatever doctrines, tactics, and hardware the U. S. intends to use for defense suppression in Europe will have to be developed and be current in the theater when hostilities begin. Commanders can adapt quickly to counter enemy initiatives if training has anticipated the need to react quickly to the unexpected. Therefore, if RPA are to be added to the defense arsenal of the United States, the development of these assets should not begin after the initiation of hostilities. The decision whether or not

these RPA will become part of the United States defense arsenal must be made now.

## APPENDIX A - C3 REQUIREMENTS FOR UNMANNED AIRCRAFT

The generic elements and/or functions of a military unmanned C3 system (at whatever level of command) can be developed in two ways.[18]. One is to focus on the cognitive functions of the "commander," (the term "commander" representing a single person or the commander plus staff at any level of the command structure.) The second is literally to list the activities that must be accomplished in each of the four major functions which make up the command-control function--- inflow of information, staff support/formulation of decision/issuance of orders, and technical machine support of information processing, storage, and communication.

Consider the following list that may be part of the cognitive functions of the commander when assigned military missions.

1. Perception of the mission and:

   a) the internal well-being of the organization;

   b) threats to the organization;

   c) capabilities of the organization to act within the existing environment at each moment in time;

   d) response of the organization (both expected and actual) to direction given.

2. Decision-making in an environment bounded by:

a) time constraints;

b) traditional response patterns;

c) historical analogies to current situation;

d) organizational motives and goals;

e) perception as set forth in time constraints.

3. Direction-giving which is bounded by:

a) limitations inherent in human communication;

b) organizational reception capabilities and patterns;

c) organizational capabilities at each point in time.

The list of activities for the major function list of items pertaining to the generic component elements of unmanned aircraft command-control are the following:

1. Inflow of Information

a. Statement of requirements for information

(1) to intelligence units

(a) at higher levels of command

(b) at units subordinate to this level of command

(2) to subordinate operational units

(3) to adjacent or cooperating operational units

b. Information on own forces

(1) status of subordinate combat and service elements

(2) status of adjacent and cooperating

units

(3) status of potential reserves

(4) reporting requirements---basic, as modified by combat/crisis situation

(a) periodicity

(b) format

(c) content/type and detail of data needed

c. Information on the enemy

(1) from subordinate intelligence and operational units;

(2) from intelligence units of higher headquarters

(a) from all available sensors/sources photint, comint, humint, elint, radint

(b) at all levels, command target sensors, recce, and surveillance systems that are survivable/robust in terms of foreseen combat environment

(3) reporting on enemy capabilities, movement, location, communication security, ECM and radar capabilities

(4) reporting requirements---basic, as modified by combat/crisis

(a) periodicity

(b) content/type and detail of data needed

(c) format

(5) functions to be performed by total intelligence process at each command level, with sophistication and completeness dependent on size and capability of staff available

(a) collection

(b) processing

(c) analysis

(d) reporting

(1) to commander

(2) to subordinate units

(3) to adjacent/cooperating operational elements

(4) to higher headquarters

(5) security of process and output

2. Staff Functions in Support of Unmanned Aircraft Command-Control

a. Operations

(1) review incoming information---own and enemy forces; environment

(2) report on current status

(a) to commander

(b) to other staff elements

(c) by direction of commander, to higher headquarters to adjacent/ cooperating units

(3) disseminate new orders on approval of commander

b. Planning

(1) review incoming information---own and enemy forces; environment

(2) review current operations to establish base for planning future operations

(3) prepare future plans for operations

(a) at the direction of commander

(b) by own initiative

(4) review incoming information---own and enemy forces; environment

c. Intelligence

(1) review incoming intelligence information

(2) collation

(3) analysis/estimating of implications of new information

(4) report preparation/briefing

(a) to the commander

(b) to other staff elements

(c) by direction of commander, to higher headquarters and to adjacent/cooperating units

(5) based on requests from commander, other staff elements, and own initiative prepare requirements for information collection

3. Commander/Decision-maker

a. Supported by actions of staff and technical services

(1) on basis of commander's stated requirements (format, periodicity, detail of content, manner of presentation, presentation aids, etc.) and staff initiative, kept current on:

(a) intelligence of enemy

(b) own force operations/capabilities

(c) potential new operations/plans

(2) on own initiative, commander maintains personal communications with subordinate commander, adjacent commanders, and higher headquarter commanders

b. Initiate activity by operations/planning staffs

(1) prepare orders for change in current operations

(2) plan for subsequent stages of operations

c. Initiate activity by intelligence staff

(1) to improve operations

(2) to gain new information

d. Issue orders for change in new operations

(1) on basis of orders from higher headquarters

(2) on own initiative, but with approval of higher headquarters as required

e. Control/maintain oversight of response to this order

(1) by requirements for reporting

(2) by use of reconnaissance by own staff members

4. Technical Support

a. communications---adequate functioning of communications network in combat environment. Network of facilities connecting subject command with higher and subordinate headquarters. Facilities must be:

(1) adequate to foreseen information flow

(2) secure and/or jam resistant

(3) accurate in transmitting information

(4) survivable/robust in combat environment foreseen

b. computer support

(1) information handling

(2) decision aids

The above listed items are by no means a complete analysis and were offered only as an illustration of the

methodology and a point from which the development of unmanned aircraft C3 requirements could be refined after several iterations of the phased process. If a structured analysis is continued using the phased approach the information needs of the RPA C3 system will become explicit and hence subject to criticism and improvement.

## APPENDIX B - UNMANNED AIRCRAFT SYSTEM COST EFFECTIVENESS

An excellent cost effectiveness study [19] of potential remotely piloted aircraft (RPA) missions yielded the following conclusions: "Manned aircraft with unguided bombs may be acceptable for undefended targets, but result in extremely high mission costs and crew losses for operation against heavily defended targets. With laser-guided bombs, manned-system cost-effectiveness is much improved, but air crew losses due to high attrition of the close-in designator aircraft may be unacceptable for heavily defended targets. Use of small, reusable RPA target designators to replace the manned designator for delivery of laser-guided bombs eliminates the low air crew survivability levels of the manned designator, and further reduces mission cost by a factor of four in strong-defense environments. An expendable air-launched RPA designator has the same effect on air crew survivability, but mission cost is about a factor of two or three higher, even though RPA launch and recovery field operation are eliminated. An RPA delivering laser-guided bombs has the lowest operational cost of all systems evaluated and performs its mission without risk to a crew, although field operations are complicated by additional command and control launch, and recovery functions. An alternative to RPA is the use of the stand-off missiles on manned aircraft with mission costs

fifteen to twenty-five times greater than RPA; there is some risk to the air crews, but it is at the lowest level of all manned systems studied. Stand-off missiles are also competitive in cost with manned delivery of laser-guided bombs at high defensive attrition levels. RPA delivering unguided bombs are not competitive with manned aircraft at low defensive attrition, nor with RPA with laser-guided bombs; however, they are more cost-effective than manned aircraft with unguided bombs above an attrition level of 0.0035. RPA delivering stand-off missiles do not offer any cost advantage over manned aircraft delivery systems."

"A small reusable RPA target designator equipped with a laser to mark the target is an attractive and versatile system and can be used with a number of different laser-directed weapon delivery systems to provide low mission costs and insensitivity to defensive capability. Use of a Boeing 747 -type aircraft as a carrier and platform for delivery of long-range laser-guided weapons operating with a RPA target designator offers a particularly versatile and cost-effective system."

"In general, RPA missions will concern strike using laser designation and multiple weapon delivery. To perform such missions, the RPA will be guided by automatic means through portions of the scenario with the human operator serving as a monitor and providing instructions by mission phase with override capability for manual control only as this appears to be required by the particularities

of the situation. Missions with other intent will also depend upon significant levels of automation although the particular tradeoff between onboard computation and computation at the control site remains to be determined."

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